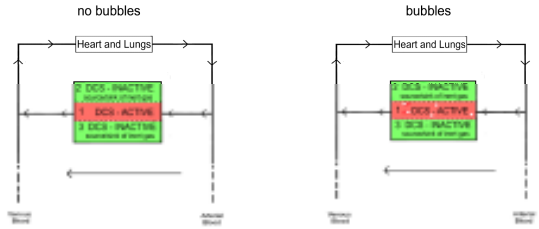
Elastic Forces in Tissues: Implications for Decompression Modeling

Saul Goldman

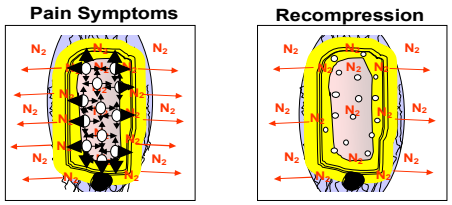
Department of Chemistry and the Guelph-Waterloo Physics Institute, University of Guelph, Guelph, Ontario, N1G 2W1, Canada.

Interconnected Three-Compartment Models, With and Without Bubbles



THE RUFFINI TYPE-2 PAIN-SENSING ORGANELLE

[FROM M. STRAUSS ET. AL. (2008)]



Stretch response from bubbles distending perineurium

Bubble reduction with resolution of pain contracting perineurium

DISSOLVED VS SEPARATED PHASE RISK FUNCTIONS

DISSOLVED OR 1-PHASE RISK FUNCTION

In the usual 1-phase (or dissolved phase) models the risk function is given by:

$$r_1(t) = C_1(\Delta P - B_1)/P_0 \qquad (1)$$

where $\Delta P = (P_g - P_0)$, (P_g, P_0) are the bubble pressure and external pressure respectively, and (C_1, B_1) are constants.

SEPARATED OR 2-PHASE RISK FUNCTION

In the ICBM(3) model, the risk function is set equal to the elastic free energy $[\Delta\Phi\ (elas\ )]$, of the stretched medium that surrounds the bubble. Here:

$$r_2(t) = \Delta\Phi\ (elas\ ) \equiv C(\Delta P - (2\gamma/R_g))^2 \equiv C_2(\Delta P - B_2)^2 \qquad (2)$$

where (B_2, C_2) are constants [GOLDMAN, J CHEM PHYS **131**, 184502 (2009)]. Thus the effect of bubbles in the ICBM(3) model is handled ***entirely*** by a very simple change in the form of the risk function.

MODEL CALIBRATIONS

Model (# compartments)	*# Fitted Parameters*	*Akaike's Information Criterion (AIC)* [a,b]
Two-Compartment Parallel PCM(2) Not bubble-based	4	500* (WORST)
Three-Compartment Interconnected ICM (3) Not bubble-based	4	469* (MIDDLE)
Three-Compartment Interconnected ICBM (3) Bubble-based	4	450* (BEST)

[a] AIC= 2[# Fitted Parameters- Ln(*L*)], *L*= "Maximized Likelihood Function"

[b] Calibration dataset : Approx 2200 exposures, all air, consisting of a mix of recreational and military profiles. Average hit rate was about 4%.

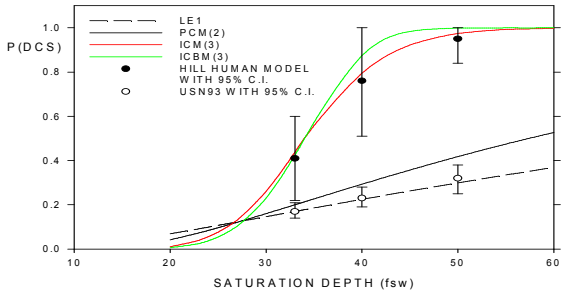
* Lowest AIC gives the best model

Observed and predicted hit rates for very-low risk recreational diving

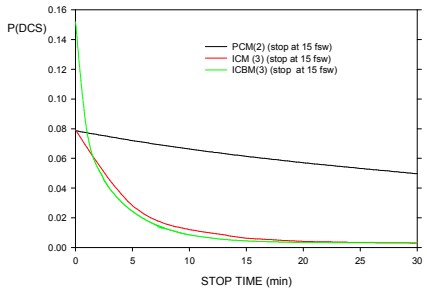
Model	*# Parameters*	*% DCS*	
		Predicted	*Observed* Mean, 95% BCI*
LE1 (Calibrated elsewhere)	12	0.062	0.015 (.007-.027)
PCM(2)	4	0.20	0.015 (.007-.027)
ICM(3)	4	0.013	0.015 (.007-.027)
ICBM(3)	4	0 .014	0.015 (.007-.027)

* Based on 67,679 air-only dives, with 10 hits. This is a preliminary sub-set of the approximately 140,000 PDE dataset, provided courtesy of Dr. Petar Denoble (DAN). This subset is mostly from live-aboard diving, with smaller numbers of day-boat diving, cold-water wreck diving, and recreational dive professionals in the Caribbean and Brazil, diving mostly from day-boats.

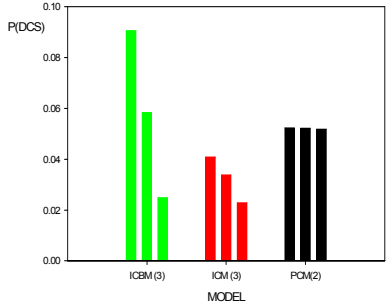
P(DCS) FOR VERY HIGH RISK DIRECT ASCENTS FROM SATURATION



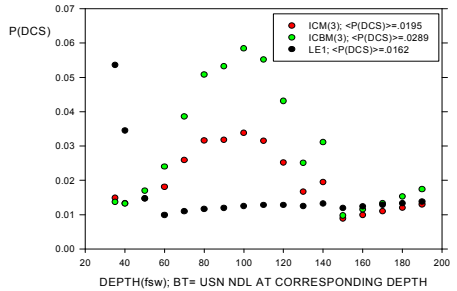
EFFECT OF STOP TIME ON P(DCS) FOR A DIVE TO 120 fsw FOR 30 min



Effect of ascent rate on P(DCS) for a no-stop dive to100 ft for 25 min
Ascent rates form left to right: 100'/min, 60'/min, 30'/min



P(DCS) FOR 17 SQUARE PROFILES DEPTH: 35-190(fsw); BT=USN NDL AT CORRESPONDING DEPTH



ACKNOWLEDGEMENTS

I WOULD LIKE TO THANK THE NATURAL SCIENCES AND ENGINEERING RESEARCH COUNCIL OF CANADA **(NSERC)** FOR FINANCIAL SUPPORT IN THE FORM OF A DISCOVERY GRANT, **SAMUEL CAMPBELL** FOR HIS HELP WITH SOME OF THE CALCULATIONS, AND **DRS. PETAR DENOBLE AND DICK VANN (BOTH OF DAN)** FOR PROVIDING A PRELIMINARY SUBSET OF THE PDE DATASET.